digital APPLICATION NOTE

NO. 102 COMPUTERS IN SECONDARY EDUCATION

It is becoming more and more important that secondary schools give students a basic knowledge of computers. Students who are going on to college will need to use computer concepts in mathematics, science, and engineering studies. For the business or general student, the insight gained in computer subjects will produce a better understanding of the role computers will play in his future. For the technical vocational student, the knowledge of a computer can open a rewarding career in the computer industry.

THE SMALL COMPUTER IN THE CLASSROOM

A few years ago educators and computer experts were forecasting that someday, well in the future, computers would be small enough and priced low enough to be used in high school classrooms. This forecast has come true sooner than expected. Now, in the classroom, small inexpensive computers are being used as demonstration devices in mathematics, physics, and general science classes. They give students a means of experimenting with important mathematical concepts and educate advanced students in the elementary theories and techniques of the computer sciences.

Teachers find the presence of the small computer to be a stimulant to the student. Under his direct control the computer excites his reasoning process and causes him to dig deeper into problems than he otherwise would. The small classroom computer also encourages students to pursue his learning further by using it after scheduled school hours.

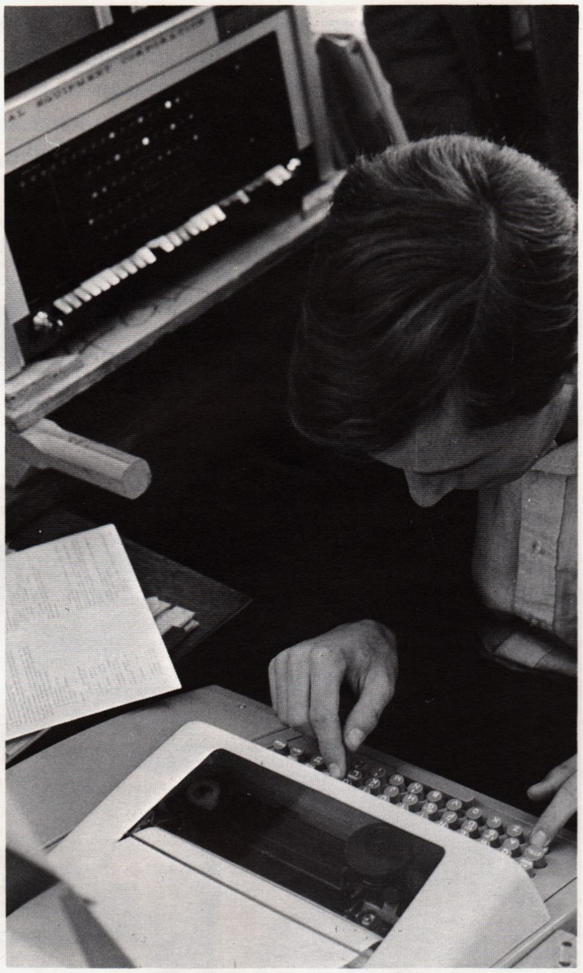
The following applications, describing the use of Digital Equipment Corporation's small computers, (PDP-8, PDP-8/I, PDP-8/S), are representative of this "hands on" approach to computer instruction in the secondary school. They typify the overwhelming acceptance of the computer by both teachers and students. What these approaches all have in common is experimentation and investigation. Not satisfied to relax and boast of their accomplishments, these teachers are constantly seeking ways to improve their programs.

SECONDARY SCHOOL APPLICATIONS

The Pomfret School, Connecticut

The Pomfret School, Pomfret, Connecticut, has developed an accelerated teaching program around DIGITAL's PDP-8 computer. The program is designed to furnish every boy in the school's 215-member student body with a basic knowledge of computer operation and programming. Computer time is woven into the curriculum. Assignments to be carried out on the computer are given in all science and math courses. These include problems that teachers might ordinarily hesitate to assign because of the amount of time required to solve them.

When the program began only five or six boys had any knowledge of computer operation. It was decided that those students who had two years of science and one year each of algebra and geometry would be selected for the initial training program. Thirty-four boys qualified.



WORKING WITH THE NEW TEACHER—Two weeks after the start of Pomfret's teaching program using a Digital Equipment Corporation PDP-8 computer, 28 of the 34 original boys selected for the initial course had developed a working program for solving a quadratic equation.

One week of instruction on computer fundamentals, programming techniques, and FORTRAN was given. Then the participating students were given a qualifying program to run on the computer. The assignment involved programming the solution (the value of X) of the quadratic equation $AX^2 + BX + C = 0$ for all possible values of A, B, and C. The resulting program was regarded as a quiz and the students were given a mark of A or E, depending on whether their program was successful. The boys were left largely on their own to do the assignment, with very little help or guidance given by the instructor. Two weeks after the course ended, 28 of the 34 boys had developed a working program for the quadratic equation.

The students found they gained a tremendous amount of knowledge and skill when allotted free access to the computer. They also gained insight into the problem through their effort to program it.

Using the approach developed with this first group, the school went on to provide the remainder of the student body with a short computer course adjusted to each level of mathematical maturity. In a matter of a few months all students had been trained to use the computer, and went on to work more complicated problems.

Fresno, California

At a Fresno, California high school, a DIGITAL PDP-8/S computer is used as an aide in teaching mathematics.

Students sign up for computer time between 8 a.m. to 4 p.m. Problems conducted with the PDP-8/S range from arithmetic through calculus, and are all taken from standard high school texts. They include finding roots using quadratic formulas, and using Newton's method, generating trigonometric and log tables, solving statistical problems, finding matrices, and using law of sines and cosines.

The Fresno high school students keep the computer busy the entire day, including lunch hour. One teacher commented that, at the close of the school day, whereas most students go home, the "computer bugs" stay until the teacher runs them out, sometimes as late as 6:30 p.m. He added that in order to use the computer himself he must come to the school on Saturdays and Sundays. When he does, however, some of the students invariably see his car and show up at the door of the computer room without notice. Students have also formed a computer club on their own, sought out a sponsor, and have had guest speakers.

The Highland Park/Deerfield, Illinois

The Highland Park and Deerfield High Schools in Illinois share a PDP-8/S computer. It resides at Deerfield with an experimental data phone connection to Highland Park. The computer is used in two ways: to demonstrate concepts in mathematics to all levels of classes, and to teach actual computer programming and operation.

To demonstrate concepts of mathematics, eight teachers from both high schools held a four-week summer workshop to write a booklet of FORTRAN programs for use in algebra, geometry, analysis, statistics, and calculus courses.

Karl Wildermuth, Chairman of the Math Department of Deerfield High School, said that teachers use the FORTRAN programs they developed in two ways: (1) To give repeated examples of a concept that they have already proven to the class —to illustrate that the theory is correct (deductively); or (2) to give repeated examples of a concept that they have *not* proven to the class—so that students might be able to find the general rule for themselves (inductively). Homework answers could be compared to the answers produced by the computer, thus giving the students the added incentive of matching the computer.

To implement Deerfield's second objective of teaching actual computer and programming operation, the school offered a semester course, Fundamentals of Digital Computation. (See Figure 1 for the time block outline of this course.) So many students were interested in Fundamentals and its "hands on" approach that two sections had to be scheduled the second year.

In addition to Fundamentals, which requires the students to have had four or more years of math, Deerfield began a new, six-week course called M-16 for underclassmen. M-16, a noncredit elective course, accomplishes the following:

- It enables students to make use of the computer in their high school courses.
- It trains students to be computer operators to assist teachers in classroom computer use.
- It prepares students for the credit course, Fundamentals of Digital Computation.

FIGURE 1
DEERFIELD—HIGHLAND PARK
HIGH SCHOOLS
COURSE OUTLINE
for
FUNDAMENTALS OF DIGITAL
COMPUTATION

Week		Topic
1	I.	Number Systems and Codes (ex: decimal, binary and octal operations; codes and subtraction by complementation)
2-3	II.	Fundamentals of Boolean Algebra (ex: definitions, logic blocks, laws of combination)
4-5	III.	Boolean Visual Aids (ex: Venn and Veitch Diagrams)
	IV.	Truth Tables and Designation Numbers (ex: development of truth tables, proving identities, designation numbers)
6	V.	Problem Solving (ex: logic blocks in electronic applications, Boolean Algebra and designation numbers)
7-8	VI.	Components (ex: series and parallel circuits, power, combination circuits, diodes, basic semiconductor physics, flip-flop, half adder, full adder)
9	VII.	Input-Output Media (ex: punched cards, paper tape, magnetic tape, magnetic ink)
	VIII.	Alpha-Numeric Codes (ex: Hollerith; 7-bit punched tape; 5 and 8 channel code; 7-bit magnetic tape)
	IX.	Internal Storage Devices (ex: Core, magnetic drum, disk)
	X.	Input-Output Devices (ex: card readers-punches; paper tape readers-punches; magnetic tape units; cathode ray tube; optical scanners; magnetic character sensors)
10	XI.	Flow Charting
	XII.	Computer Languages (ex: FORTRAN, AGOL, MAD, BALGOL, JOVIAL, NELIAC, COBOL, IT)
11-12	XIII.	PDP-8/S Software (ex: FORTRAN, FOCAL, PAL III, MACRO-8, Editor, Loader, DDT, ODT)
13-17	XIV.	Programming and Computer Operation
18	XV.	Report on Projects

Note: Approximately one day per week reserved for utilization of FORTRAN and Calculator.

Deerfield not only has a classroom computer, but increased its availability by locating the computer in a laboratory equipped with closed-circuit TV, so that any of ten math classes can view computer demonstrations simultaneously. The laboratory's two-way voice communication system enables teachers to specify data. Student computer lab assistants enter programs, type in data, focus the TV camera on the output, and explain and interpret the results.

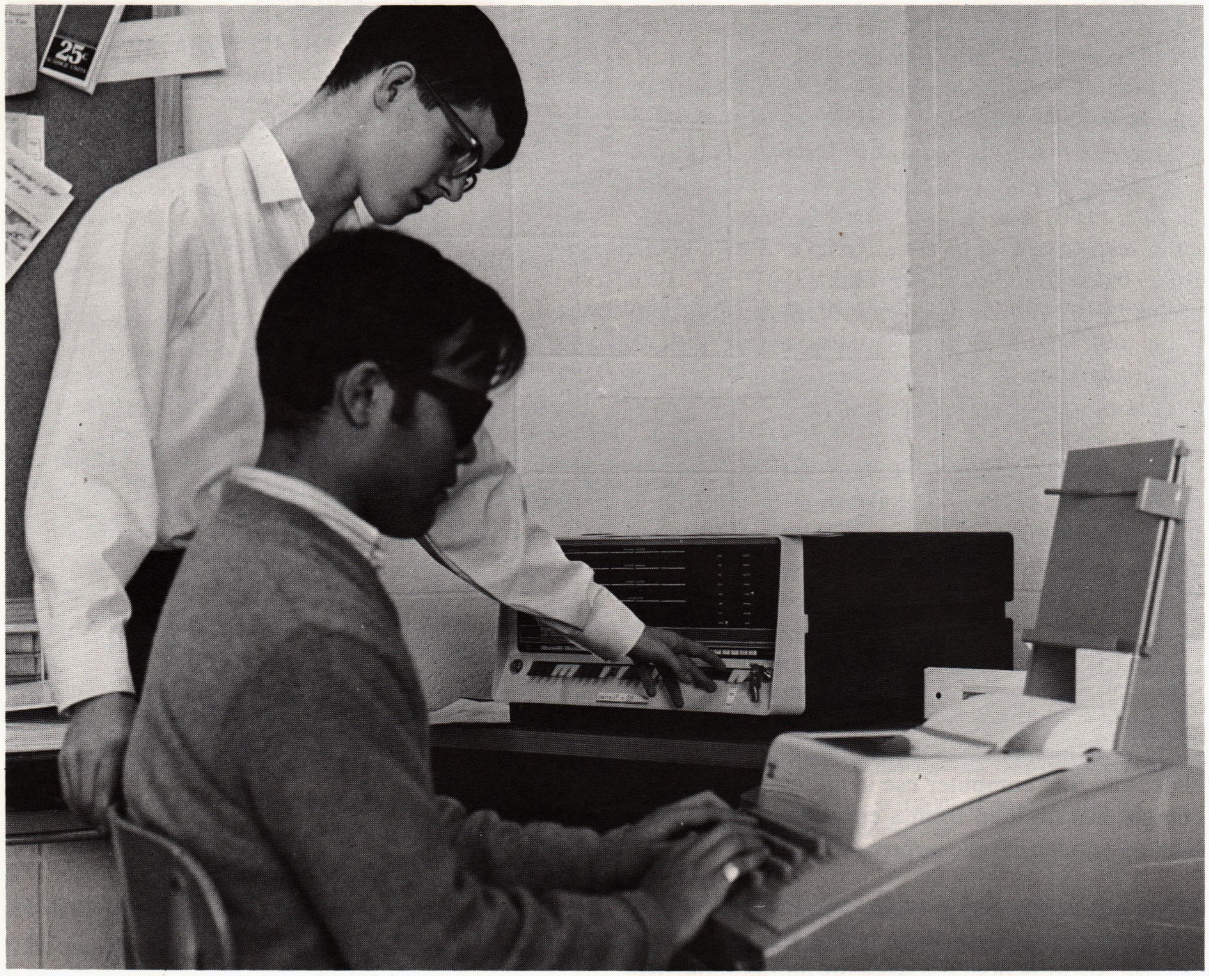
Hamden, Connecticut

Hamden High School in Connecticut also has chosen a small DIGITAL computer to aid in teaching math. Richard Bigelow, Planning Coordinator for COSSECC (Connecticut Suburban and Shoreline Educational Computer Center), which has its headquarters at Hamden, felt that the time had come when "more elaborate equipment was necessary for applied math." Hamden offers to juniors and seniors, Computer Mathematics, an elective course which uses the FORTRAN Language. Their approach gets the students programming on the computer as quickly as possible.

Although underclassmen are not included in Computer Mathematics because of the math background judged necessary, Hamden High School has organized two extra-curricular computer activities which welcomes all students. One activity uses FORTRAN, the other uses FOCAL, a new conversational language developed by Digital Equipment Corporation specifically for educational applications. No computer science course is offered or proposed, according to Mr. Bigelow. Hamden's objective is to use the computer strictly as a tool.

This same view is held by Gilford and Amity High Schools, the two other schools in COSSECC using their own computers. These two schools combine the computer with material presented in Algebra II, Calculus and Trigonometry, rather than schedule a separate course.

South Windsor, Connecticut



STUDENTS TAUGHT FORTRAN—A DIGITAL PDP-8/S computer is used at South Windsor High School in Connecticut to familiarize students with the FORTRAN language as part of the school's computer science course.

Using a computer for simultaneous development of certain math principles and computer fundamentals is South Windsor, Connecticut, High School.

Miss Ann Duffy teaches a computer science course to "slightly above average students—115 to 120 IQ." To achieve her objective of fully acquainting the students with the syntax of the FORTRAN language, she feels that a knowledge of assembly language programming is necessary first. She devotes twenty lessons, about half her course, to complementation, distributive law, algorithmic techniques, base conversions, machine, and assembly language before she goes on to FORTRAN.

Next year, South Windsor's second with a computer, 7th and 8th graders will be taught machine language, and 9th graders FORTRAN. The more advanced sophomore, junior, and senior math courses will use the computer as a tool. Other math classes will have the iterative technique of problem solving demonstrated via the computer. At least 50% of the students at South Windsor will get some contact with the computer next year. Miss Duffy wants to reach as many students as possible because she believes there is a place for people of various levels of ability to work with computers.

THE COMPUTER IN THE TECHNICAL SCHOOL

Ottawa Technical High School

A number of technical-vocational schools are using small computers in conjunction with training devices to teach digital logic. Ottawa Technical High School in Ottawa, Ontario, Canada is typical of this effort. The school offers training in computer technology on its small DIGITAL computer. Boys from the Four-Year and Five-Year[1] Programs take courses of varying depth in programming and digital techniques. The course outline for grade 13 and the Four-Year grade 12 Electronics majors is shown in Figure 2.

Carl B. Weick, director of the computer technology program, said most students of average intelligence are able to program and debug their assigned problem. Twenty-two out of 25 students had either submitted complete tested programs or were engaged in various stages of tape preparation two-thirds of the way through the term.

Mr. Weick said that the computation area is operated as a facility independent of the electronics shop, and that computer use in all the mathematics courses has resulted from a curriculum revision to include an algorithmic approach.

Plans are underway to make possible a major in computer technology. Boys taking this option will receive up to 8 hours a week in the lab, and will take a basic electronics course in grade 11 and Digital Techniques in grade 12. They will be taught maintenance procedures on Input/Output equipment as well as logic circuitry for the purpose of providing them with a salable skill as a computer technician upon graduation.

In conclusion Mr. Weick said, "The basic aim at Tech is still to produce a good high school graduate. We feel we can do a better job by exposing students to computer education."

FIGURE 2

COMPUTER TECHNOLOGY CORE PROGRAM

1 School Term—2 Periods Per Week

I BINARY ARITHMETIC
1. Binary Number System
   —Base, Radix, Conversion Between Bases
   —Addition, Subtraction, Ones and Twos Complement, Multiplication, Division
   —Octal Notation
   —BOD

Labs in this Section
—Interpretation of Computer Console Lights
—Recovery of Contents of memory
—Switch action on console

II COMPUTER ELECTRONIC CIRCUITS
1. How Binary Numbers are Displayed.
   —Indicator Lamps etc.
2. How Binary Numbers are Stored.
   —Switches
   —Flip Flops
3. How Binary Numbers are operated on.
   —Games
   —Truth Tables
   —Elements of Boolean Algebra
   —Simple logic design
4. A to D and D to A Conversion

Labs in this Section
—Flip Flop
—Counter
—Shift Register
—Composite Register
—Analog to Digital Conversion
—Digital to Analog Conversion
—Micrologic Experiments

III COMPUTER PROGRAMMING
1. Oragnization of a Digital Computer
2. Command Structure—The Machine Language
3. The Input—Output Devices
4. Flow Diagraming a Program
5. Coding a Program
6. Assemblers and Debugging
7. Interpretive Programs and Language—Fortran

Labs in This Section
—Tape Preparation
—Loading
—Programming Problems in Ascending Complexity
  —One shot one pass
  —Branching
  —Looping
  —Subroutine linkage
  —Address Modification
  —External Program Control
    —Via teletype or its reader
    —Via switch registers on console

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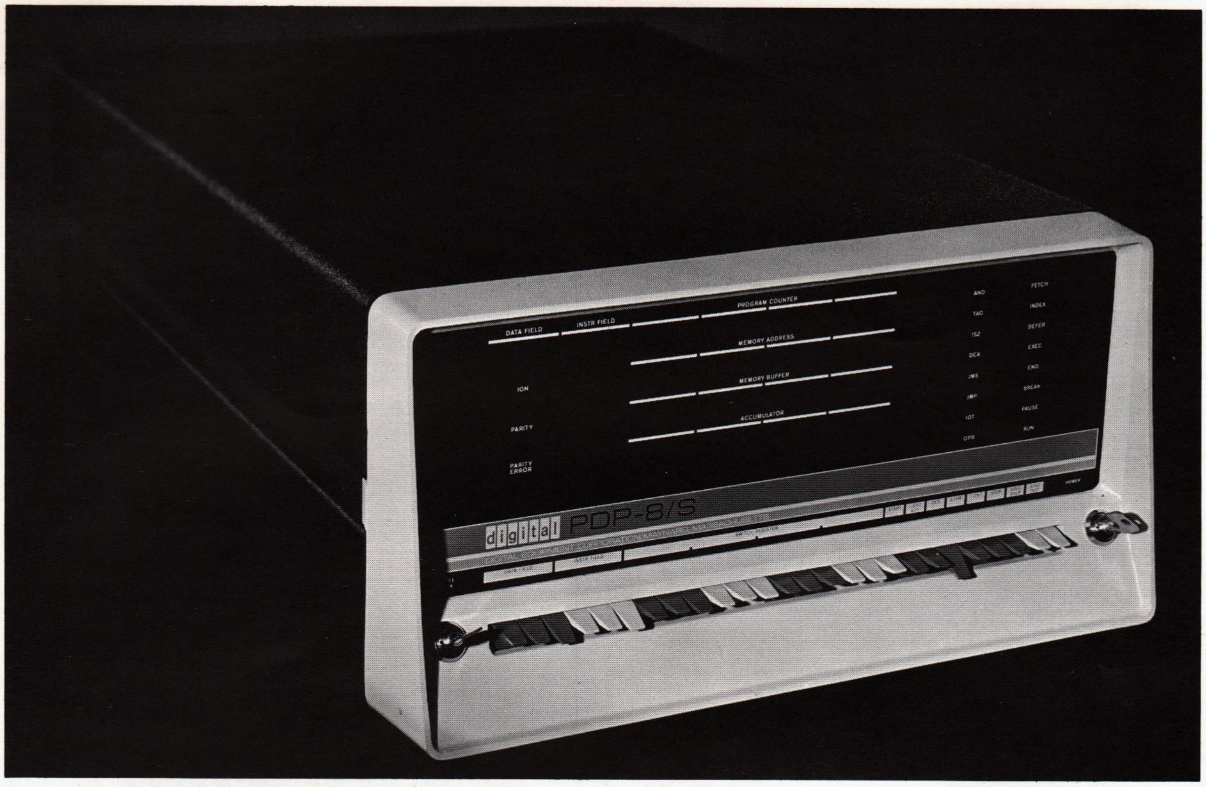
[1] In the Four-Year course boys traditionally enter some form of apprenticeship. The Five-Year graduates are traditionally preparing for higher education. To help the selected Four-Year boy compete with his Five-Year counterpart at higher institutions, the school offers a One-Year Special grade 13 course.

DIGITAL'S PACKAGE FOR COMPUTER EDUCATION



LOW COST CLASSROOM COMPUTER— Digital's PDP-8/S is the first general purpose computer to sell for under $10,000. It is available on a lease basis for educational use.

THE COMPUTERS

The small computer is a far cry from the room full of complicated equipment of a decade ago. Teachers inexperienced in the use of computers can be taught to take full advantage of these compact, easy-to-use machines in a matter of weeks.

Digital Equipment Corporation, the world's leading manufacturer of small general purpose computers, has a strong commitment to education. We have developed the equipment, programs and training to support the educator in his efforts.

More of our low cost PDP-8 class of computers (PDP-8, PDP-8/I and PDP-8/S) are installed in scientific/engineering and educational applications than any other small general purpose computers ever made.

Because they are general purpose, they are flexible, easy-to-learn, and easy-to-use. They can be expanded by using additional memory, input/output devices and other equipment as needs grow. The PDP-8/S computer, for example, a fast 4096-word random access core memory expandable system is operating successfully in nearly 1000 installations, many of them in the educational field. It is the first full scale computer to sell for under $10,000. The PDP-8/S computer, including maintenance, is also available on a lease basis.

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39 Months Leasing

Typical Configuration

465	8/S + ASR 35 Teletype
92	PCO2 High Speed Reader
130	ASR 35 (off line)
$687	Per Month

A disc memory system and various additional options are available at a slightly higher rate. Contact your nearest Digital Sales Office for complete details.

PROGRAMMING PACKAGES

digital
DEC-08-ESAB-PB
PDP-8 Editor
8/4/67
High + Low Speed Combined
DIRECTIONAL TAPE
digital SMALL COMPUTER HANDBOOK
C-800
digital PDP-8/S SOFTWARE MANUAL
digital PDP-8/S SOFTWARE MANUAL
digital PDP-8/S MAINTENANCE MANUAL
digital PDP-8/S SOFTWARE MANUAL
digital
digital
DEC-08-AFC
Fortran Compiler
9/13/67
digital
PAL III
2/24/67
BINARY

PROVEN PROGRAMMING PACKAGE—DIGITAL'S standard programming package has been proven in over 2000 small computer installations. It includes FOCAL, a new conversational language designed specifically for education.

The standard programming package, which is included in the basic price of these computers, has been proven in over 2000 installations. In addition to traditional FORTRAN, Calculator, and PAL III assembler programs, DIGITAL has developed FOCAL (Formula Calculator), a new conversational language that permits the student to formulate his problem step by step while sitting at the computer. As soon as these steps have been completed, they can be executed and the results checked. Steps can be quickly changed, added, or deleted.

Primarily designed for educational use, FOCAL takes an hour or two to learn. It provides a set of simplified techniques that permits the student to communicate directly with the computer. The student therefore has the advantages of the computer at his disposal without the requirement that he master the intricacies of programming.

Focal Example

In the following sample FOCAL program, the computer asks the user to set his parameters and list his variables. Then solves for mean, sample variance and standard deviation.

```
*WRITE ALL
C-FOCAL., 1968

01.01 ERASE
01.10 ASK "HOW MANY DATA ARE THERE?" N,!"PLEASE LIST YOUR DATA."!
01.30 FOR I=1,N; ASK X(I)
01.40 FOR I=1,N; DO 3
01.50 SET XN=N; SET XMU=SMX/XN
01.60 SET VAR=SQX/XN-XMU↑2
01.70 SET SGMA=FSQT(VAR)
01.80 TYPE %,!"MEAN",XMU,!"VARIANCE"VAR,!"SIGMA"SGMA,!
01.90 QUIT

03.10 SET SMX=SMX+X(I)
03.20 SET SQX=SQX+X(I)↑2

*GO
HOW MANY DATA ARE THERE?:10

PLEASE LIST YOUR DATA.
:2 :3 :4 :3 :4 :5 :4 :5 :6 :5

MEAN=+0.410000E+01
VARIANCE=+0.129001E+01
SIGMA=+0.113579E+01
*
*GO
HOW MANY DATA ARE THERE?:15

PLEASE LIST YOUR DATA.
:34 :67 :89 :40 :75 :65 :52 :86 :76 :82 :79 :56 :79 :80 :44
MEAN=+0.669333E+02
VARIANCE=+0.291262E+03
SIGMA=+0.170664E+02
*
*GO
HOW MANY DATA ARE THERE?:5

PLEASE LIST YOUR DATA.
:1489 :89999 :432 :2000 :2020

MEAN=+0.191880E+05
VARIANCE=+0.125388E+10
SIGMA=+0.354102E+05
```

Other languages vary in degree of problem difficulty, but all can be learned in a relatively short period of time.

FORTRAN, more advanced than FOCAL is a universal language which has found wide acceptance in secondary schools. FORTRAN, short for "formula translation," means that you can translate the formula you wish to solve into source statements, which are basically a computer shorthand.

Fortran Example

This example asks the user to create a regular polygon by typing in the number of sides. In step 2, the computer tests the number to see whether it is a legal number.

If legal, the program asks for the length of a side, tests for a positive number and solves for Apothem, perimeter, and area.

If either of the user inputs are illegal, the computer indicates the error and asks the user to start again.

This conversation between the student and the computer will follow the format below:

```
C;     AREA OF A REGULAR POLYGON
C;     GIVEN: THE NUMBER OF SIDES AND THE LENGTH OF A SIDE
14;    TYPE 1
1;     FORMAT (/,"PLEASE TYPE NUMBER OF SIDES",/)
       ACCEPT 2, XNUM
2;     FORMAT (E)
       IF(XNUM-3.)3,5,5
3;     TYPE 4
4;     FORMAT(/,"TRY TO DRAW A POLYGON WITH THIS MANY SIDES",/)
       GO TO 14
5;     TYPE 6
6;     FORMAT(/,"PLEASE TYPE LENGTH OF SIDE",/)
       ACCEPT 7,XLEN
7;     FORMAT (E)
       IF(XLEN)8,10,12
8;     TYPE 9
9;     FORMAT(/,"YOUR POLYGON MUST BE INSIDE OUT",/)
       GO TO 14
10;    TYPE 11
11;    FORMAT(/,"ARE YOU TALKING ABOUT A POINT?",/)
       GO TO 14
12;    XPER=XNUM*XLEN
       XRAD=(360./XNUM)*.0174533
       XCOT=COSF(XRAD/2.)/SINF(XRAD/2.)
       XAPM=XLEN/2.*XCOT
       AREA=(XAPM*XPER)/2.
       TYPE 13,XAPM,XPER,AREA
13;    FORMAT (/,"APOTHEM IS",E,/,"PERIMETER IS",E,/,"AREA IS",E,/)
       GO TO 14
       STOP
       END
```

```
PLEASE TYPE NUMBER OF SIDES
2

TRY TO DRAW A POLYGON WITH THIS MANY SIDES

PLEASE TYPE NUMBER OF SIDES
5

PLEASE TYPE LENGTH OF SIDE
4

APOTHEM IS +0.275276E+1
PERIMETER IS+0.200000E+2
AREA IS+0.275276E+2
```

PAL III is closer to machine language (binary) than any of the others. Students who are interested in programming or are interested in the technical aspects of the computer find the knowledge gained from the use of PAL III extremely helpful in developing an in-depth understanding of the computer. The knowledge of PAL III forces a close examination of the way a machine operates.

When using the computer as a tool, FOCAL, or FORTRAN are enough. But, for a future in advanced programming or a technical skill, a detailed knowledge of the machine is necessary and obtainable using PAL III.

TEACHER TRAINING

To complement its hardware and software commitment to the educator, DIGITAL, has established one of the most comprehensive training programs in the industry. Because DIGITAL's small computers are relatively inexpensive, they are often the first computer a customer has owned. We have developed the kind of training these people need. These courses, included in the basic price, are the most complete in the small computer field.

DIGITAL's computer users can become members of the Digital Equipment Computer Users Society and join nearly 2000 Family-of-Eight users already there. Through DECUS they have access to an expanding library of programs and other materials. Users can also contribute to and receive DECUSCOPE, a monthly newsletter containing user techniques, routines, and program summaries.

A DECUS educational subgroup is currently being formed which will promote program exchange, organize meetings of educators to compare ideas on course outlines and problems, and keep up to date on research being conducted in educational techniques at the university level.

In addition, the number of DIGITAL machines already installed insures you a world-wide field service staff ready to provide you with fast, efficient attention should the need arise.

Further information on the above applications, other uses of DIGITAL's computers in secondary education, or complete details on the computers or financing plans mentioned in the booklet can be obtained by writing to Educational Applications, Digital Equipment Corporation, 146 Main Street, Maynard, Mass., or from your local Digital Sales Office listed on the back cover.

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